The New German Water Loss Regulations in context with other international applications of the IWA water balance and real loss performance indicators

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ABSTRACT

In Germany, leakage management was never as much of an issue as in England. The infrastructure is in relatively good condition, preventive maintenance is done excessively, and billions of Deutschmark were spent since World War II to renew, rehabilitate and extend the distribution networks. Leak detection is done as a routine maintenance, very often by calling in contractors. All of this would not be worth mentioning if there was no other news. But there are news - the new W 392 guidelines, issued by the DVGW (Deutsche Vereinigung des Gas- und Wasserfaches e.V., which translates to German Association of the Gas and Water Sector). These new guidelines (published Mai 2003) are titled:

W 392 - Network inspection and water losses - activities, procedures and assessments.

This paper provides for the first time an English language summary of the W 392 guidelines, analyses the recommended methodology and targets and puts them in context with other national standards and recommendations which are based on the IWA methodology.

KEYWORDS

W 392, Water Loss Reduction, German Guidelines

INTRODUCTION

In Germany, leakage management was never as much of an issue as in England. The infrastructure is in relatively good condition, preventive maintenance is done excessively, and billions of Deutschmark were spent since World War II to renew, rehabilitate and extend the distribution networks. Leak detection is done as a routine maintenance, very often by calling in contractors.

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- W 392 - Network inspection and water losses - activities, procedures and assessments[1]

replace three old guidelines, namely

- W 390 - Control of Water Supply Networks[2]
- W 391 - Water Losses in Water Distribution Systems[3]
- W 393 - Leak Detection Methods for Water Supply Pipelines[4].

Instead of translating the entire guidelines, a brief summary will be given and only key statements will be quoted[5]. Furthermore, the most important changes to the old guidelines will be highlighted and, where necessary, discussed.

[1] Rohrnetzinspektion und Wasserverluste - Massnahmen, Verfahren und Bewertungen
[2] Überwachung von Trinkwasserrohrnetzen
[3] Wasserverluste in Wasserverteilungsanlagen
[4] Verfahren zur Leckortung an Trinkwasserleitungsnetzen
[5] The focus of the translation was to convey the technical meaning of the text as accurately as possible. Accurate word by word translation was therefore not always possible.

STRUCTURE

The main headings of the guidelines are:
1. Applicability
2. Standards and legal framework
3. Principles
4. Inspection of water supply systems
5. Water losses in water supply networks
6. Methods and measures for monitoring and reduction of real losses
7. Appendices

The main focus of this paper will be on Chapter 5: water losses in water supply networks. However, a brief summary of the other chapters will be given as well.

CHAPTER 1: APPLICABILITY

These guidelines are applicable for the inspection of water distribution networks of public[6] *water supply systems. Inspection of water distribution systems in the spirit of these guidelines means (i) assessment and analysis of the system condition, (ii) calculation and analysis of water losses and (iii) water loss reduction measures.*

In principle these guidelines may also be used for regional water schemes (bulk suppliers), raw water systems and industrial (company) distribution systems.

CHAPTER 2: STANDARDS AND LEGAL FRAMEWORK

This chapter consists of a long list of DIN standards, DVGW guidelines and other legal acts and norms which are quoted in the text of W 392 and therefore form an integral part of the guidelines. The list ranges from general laws to detailed technical standards (e.g. corrosion protection).

CHAPTER 3: PRINCIPLES

Chapter 3 talks about comprehensive maintenance. It starts with the definition of the three pillars of a comprehensive maintenance strategy, which also includes asset management. The three pillars are:

- Inspection - regular, scheduled inspection of the system and its components
- Maintenance - preventive and corrective
- Repair and rehabilitation

Key message: *as important as an effective maintenance strategy is the planning and construction phase, were an important foundation for economic operations and long technical life of the assets is laid. Issues of special relevance:*

- ***Material selection:*** *in order to ensure long asset life, soil conditions have to be taken into account when selecting pipe materials and coating, corrosion protection etc.*
- ***Establishment of district metered areas:*** *Bulk meters shall be installed at inflow points so that occurrence of leaks can be recognized.*
- ***Bulk meters*** *shall be installed on* ***transmission mains*** *so that large bursts can be recognized as early as possible*
- ***Rehabilitation:*** *Rehabilitation (replacement) of transmission and distribution mains as well as service connections shall be done in time; based on pipeline condition, burst frequency and pipeline age.*

[6] the expression public water supply systems are used irrespectively of the ownership or legal form of a water utility

Guidelines are also given for the organization of an effective maintenance strategy and it is highlighted that maintenance has to be ***goal oriented***. The following goals are stated:

- Sustaining security of supply
- Sustaining water quality
- Reducing water losses or maintaining a low level of water losses
- Recognizing defects at an early stage
- Minimizing defects

CHAPTER 4: INSPECTION OF WATER SUPPLY SYSTEMS

Water distribution systems are to be monitored and inspected for hygienic, legal economic and ecologic reasons. Inspections shall be carried out in accordance with detailed recommendations (a summary of which can be found in Table 1) an additionally in any of the following cases:

- High real losses (according to Table 4)
- High burst frequencies
- Trend of increasing water losses or sudden rise of real losses
- Unusual pressure drops
- Unusual increase in system input volume
- Noticeable increase of bursts in a certain period or in a certain part of the system
- Water hammers
- Increased operating pressure
- Soil movements on pipeline routes
- Construction activities close to pipelines
- changes in surface condition, especially of roads, like cracks or settlements
- Impact on water quality
- Customer complaints regarding operating pressure or water quality
- Issues related to security, especially in crisis situations.

The need for regular inspections to ensure accessibility of all system parts and signposting of all valves, service connection stop taps, hydrants and other appurtenances according to the applicable standards is also highlighted.

The need for comprehensive metering is mentioned (production, distribution and all consumption) and the importance of inflow measurements for real loss monitoring is once more mentioned.

Description of system part	Control and inspection measures	Maintenance measures	Period
Valves	Operability General condition Tightness of stuffing box Corrosion of visible parts Close/open position in accordance to records?	Closing and opening if operational situation allows	Every 8 years
Boundary valves	Check that in closing position Sounding to ensure tightness		Annually
Hydrants	Operability Water tightness Corrosion Functionality of all parts	Short flushing Cleaning Corrosion protection	Every 4 years
Air valves	Damages and Corrosion Functionality of all parts (dismantle) Condition of chamber	Cleaning Corrosion protection Replacement of gaskets	Annually
Flow control valves	Same as valves Plus check of functionality and settings	Cleaning Corrosion protection Greasing of moving outer parts	Annually
Non-return valves	Functionality Damages and corrosion Tightness	Cleaning Corrosion protection	Annually
Pressure Reducing Valves	Damages and Corrosion Tightness Complete closing Proper setting Functionality and setting of controllers (if applicable)	Cleaning Corrosion protection Greasing of moving outer parts Replacement of parts as required Pressure measurements, tolerance during night flow +/-5 m Correction of settings if required	Annually and if required
Marker plates	Existence Good visibility Readability Condition of plate and marker post	Cleaning Correction measures If required replacement	Together with control of respective appurtenance

Table 1: W 392 - Periodic water distribution system inspection and maintenance measures (part 1)

Description of system part	Control and inspection measures	Maintenance measures	Period
Surface boxes	Condition Level (+/- 2 cm) compared to road surface Operability of cover and accessibility of valve spindle Traffic safety	Inside cleaning Greasing Level Adjustment Repairs if required	Together with control of respective appurtenance
Chambers with appurtenances	Accessibility Control of air condition (oxygen concentration, toxic or explosive gases) Corrosion of steps, cover or other parts Water tightness of concrete Inspection of all appurtenances	Cleaning Ensure ventilation Corrosion protection Greasing of moving parts	Together with control of respective appurtenance
Cathodic protection	Control according to detailed specifications	Readjustment of settings as required Maintenance measures as recommended by the manufacturer	Annually or as recommended by the manufacturer
Bulk meters and pressure gages and loggers	Functionality Accuracy	Cleaning Replacement Calibration	In accordance to the importance of the equipment and as recommended by the manufacturer
Customer meters	Functionality Accuracy	Regular replacement	According to respective law

Table 1: W 392 - Periodic water distribution system inspection and maintenance measures (part 2)

High burst frequencies and/or high levels of real losses (according to Table 4) require frequent leak detection surveys. If there is no regular and continuous inspection program, it is recommended to schedule leak detection surveys in accordance with

Level of Real Losses **[m3/km/h]**	Recommended Leak Survey Frequency
High	Annually
Medium	Every three years
Low	Maximum every six years

Table 2: Recommended Leak Survey Frequencies

A part of this chapter deals with the monitoring of water quality and refers to the relevant DIN Standard (for example DIN 2000).

All inspection and maintenance measures have to be recorded in great detail. It is also recommended to accurately measure the position of detected leaks and prepare leak location sketches and keep these records at least until the next inspection.

CHAPTER 5: WATER LOSSES IN WATER SUPPLY NETWORKS

This chapter starts with an important statement:

A precondition for every discussion of water losses are exact definitions of the components of the water balance.

The recommended form for the water balance and the definitions of its components follow exactly the IWA recommendations from the 'Best Practice' manual (Alegre H. et al, 2000). This is seen as a major improvement to W 391, which only says: *water losses have to be calculated regularly (e.g. annually) by establishing a water balance* - without giving any guidelines or providing definitions.

Interesting is how the understanding of the reasons for real losses has changed:

W 392 (new)	W 391 (old)
The quantity of water lost from an individual leak depends on the flow rate and the runtime. - Undetected small leaks (but with long runtimes) lead to **high** water losses. - Leaks detected by active leakage control cause mostly to **medium to high** water losses. - Visible, reported bursts have high flow rates but cause only **low** water losses. This is obviously based on the English BABE (Burst and Background Estimates) concept.	Not mentioned
Length of the distribution network	Not mentioned
Service connection density - it is explained that based on country-wide repair statistics it is obvious that the number of leaks per length of main is much higher in distribution systems with service connections than on trunk mains or pipelines with a low connection density.	Depending on soil conditions, the service connection density influences the level of real losses.
Pressure - Changes in pressure result in changes in leakage levels in a nearly **linear relationship**. It is explained that the traditional square root relationship is not applicable for distribution systems as the area of the leaks also varies with pressure.	Higher operating pressures do normally **not** lead to higher levels of leakage (!) as bursts are found more quickly.
Structure of the distribution network - type of material, age, condition, corrosion protection used for pipes, fittings, valves hydrants and other appurtenances (and related quantities) influence the level of real losses in combination with installation depth and quality of workmanship influence leak frequency and level of real losses.	Density of valves, hydrants and other appurtenances is normally **not** relevant for the level of real losses.
Soil - three parameters (in all kind of combinations) are relevant: - aggressiveness (causing corrosion) - type (texture) of soil: clay or argillaceous soils lead often soil movements - visibility of leaks: leaks often don't surface in gravel and permeable rock	Type (texture) of soil is the most important influencing factor. Levels of unavoidable real losses (expressed in m3/h per km pipeline), depending on soil type, were listed in a table and a diagram (to be used for mixed soil conditions). This was the most important section of the W 391 guidelines and has been completely skipped in W 392.
	Influencing factors with only limited relevance are: - pressure - average diameter - pipe materials and types of joints - density of fittings and appurtenances - pipe depth and - type of bedding

Table 3: Reasons for real losses - comparison W 392 to W 391 (old) guidelines

Like the old W 391 guidelines, W 392 also discourages the use of percentages as a real loss indicator but reinforces the message by detailed explanations:

Expressing real losses as a percentage of the system input volume is unsuitable as a technical performance indicator as it does not reflect any of the influencing factors. Systems with higher system input volumes (e.g. urban systems) will automatically have an (apparently) lower level of water losses if expressed in percentages. Systems with low water consumption (e.g. rural systems) will show high percentage figures of real losses. Therefore comparisons using percentages will always favour systems with high system input.

Following common German practice, the recommended technical performance indicator is the volume per length of main [m3/km/h]. Presumably it was not possible to reach consensus in the German water industry to follow international best practice and express real losses per service connection rather than by length of mains. This is reflected in the following clause:

Using the connection density, the level of real losses (per km mains) can also be expressed in the internationally often used unit m3/per services connection per day.

To deal with the obviously problematic indicator losses/km, different targets are recommended for systems with different connection density:

Level of Real Losses **[m3/km/h]**	Network Structure		
	Area 1 (urban, large cities)	Area 2 (urban)	Area 3 (rural)
Low	< 0.10	< 0.07	< 0.05
Medium	0.10 - 0.20	0.07 - 0.15	0.05 - 0.10
High	> 0.20	> 0.15	> 0.10

Table 4: W 392: Guidelines for real loss levels in 3 different categories of utilities

The following definitions are given:

Low level of real losses:

According to the German definition the low level of losses can nearly be considered as unavoidable real losses.

Medium level of real losses:

Normally, real losses should not exceed the upper range given in this category, means they should not be more than two times the unavoidable real losses.

High level of real losses:

Real losses at these levels require special attention, efforts and loss reduction measures to be taken.

ANALYSIS OF THE REAL LOSS TARGETS IN W392

The German National Report on 'Water Loss Management and Techniques' (Weimer D. 2001) provides background information for the interpretation of the real loss values of Table 4:

1. Operating pressures in Germany are at an average of 30 m
2. Connection density which formed the basis for the recommendations:
   - Area 1: > 40 [connections per km mains]
   - Area 2: 25 - 40 per km
   - Area 3: < 25 per km

Using this information, the values of Table 4 can be expressed in litres/connection per day (Table 5):

Level of Real Losses **[liters/connection/day]**	Network Structure		
	Area 1 (urban, large cities)	Area 2 (urban)	Area 3 (rural)
Connection Density used for calculation	50	37.5	25
Low	< 48	< 45	< 48
Medium	48 - 96	45 - 96	48 - 96
High	> 96	> 96	> 96

Table 5: The W 392 leakage level guidelines expressed in litres/connection/day

Using the ILI (Infrastructure Leakage Index) formula for Unavoidable Real Losses

UARL = (18*Lm + 0.8*Nc + 25*Lp) * P

Lm = mains length (km)
Np = number of service connections
Lp = total length of private pipe property line to customer meter (km)
P = average pressure (m)

and assuming Lp zero for Area 1 and 2 (as predominately the case in German urban situations) and 5 m in rural situations (Area 3), the German targets translate into the following ILI values:

Level of Real Losses **[ILI]**	Network Structure		
	Area 1 (urban, large cities)	Area 2 (urban)	Area 3 (rural)
Low	< 1.38	< 1.17	< 0.97
Medium	1.38 - 2.76	1.17 - 2.50	1.05 - 2.11
High	> 2.76	> 2.50	> 1.95

Table 6: The W 392 leakage level guidelines interpreted by using the Infrastructure Leakage Index (ILI)

Interesting also the arguments for low levels of real losses:

Water loss reduction primarily has to be done for the following reasons:

- Hygiene
- Ensuring sufficient levels of supply
- Safety
- Ecology

and only in the case of high water losses there are also economic reasons for reducing them. This is clearly a totally different philosophy than in the privatized English water industry.

Detailed definitions of the water balance components are given, following exactly the IWA recommendations. It is explained that apparent losses should be assessed in detail in order to accurately determine the level of real losses. However, an indication of the average level of apparent losses is given for utilities which don't have detailed data: 1.5 - 2.0 % of the Authorized Consumption. This sounds very low but can be explained as follows:

- high accuracy customer meters
- regular meter replacement
- water pilferage is not an issue
- reliable meter reading, data handling and billing procedures and systems

CHAPTER 6: METHODS AND MEASURES FOR MONITORING AND REDUCTION OF REAL LOSSES

It is recommended to develop and implement a strategy for real loss monitoring, reduction and maintenance of a low real loss level once achieved. Such strategy should include the following:

- Calculation of water loss levels and burst frequencies
- analysis of water loss levels and their trend (increase/decrease) from a technical and economical point of view
- reduction of awareness, location and repair times
- active leakage control
- record keeping
- asset management (network rehabilitation)

For the execution of real loss control measurements, the distribution network has to be split into small areas[7]. They might be measured with permanently installed meters or on a temporary basis with portable devices. The following needs to be done:

- the area has to be measurable through one or more inflow pipes
- the size shall be determined by the length of mains, which shall be in the range of 2.5 to 20 miles (4 to 30 km)
- permanent or portable meters shall be installed
- the minimum night flow has to be established

It is recommended to split large zones into smaller areas by the installation of flow meters equipped with data loggers for short leak awareness durations.

[7] Rohrnetzbezirke = Network Districts (equivalent to DMA)

The minimum night flow method is explained, and a guideline is given how to estimate minimum night consumption:

Minimum night consumption: 0.4 - 0.8 m3/h per 1,000 supplied population[8]

This figure is applicable for areas with a population between 2,000 and 40,000 people and no industrial night use.

The second method of leakage measurement which is mentioned is the 'Zero Inflow Measurement'[9]. This method is widely practiced in Germany and other continental European countries and is based on fact that if an area is small enough, even during daytime there will be extremely short periods (maybe a second) where consumption is zero.

These measurements are undertaken with very accurate mobile flow meters (normally installed in measurement vans) and small network sections (pipe length between 1 and maximum 10 km) are valved off and supplied with a bypass (fire brigade hoses) from a hydrant outside the area to a hydrant inside the area (and this flow is of course measured). The suggested minimum duration for the measurement is 20 minutes.

This is an excellent method for networks with a relatively high fire hydrant connection density and properly functioning valves. The advantage clearly is that the existence of a leak can immediately be recognized. Leak location is also fast and easy as it might be possible to close valves to further reduce the size of the area.

Finally, a very general and brief description of available leak location techniques is given.

APPENDICES

Three appendices are included:

- a sample form sheet for 'Zero Inflow Measurements'
- a sample form sheet for valve and hydrant inspections
- an example how to calculate a water balance, which follow exactly the IWA recommendations, but the real loss performance indicator to be used is m3/h per km main

[8] This is equivalent to 0.4 - 0.8 l/capita/hour. This is at the low end of what was found during the most recent UK Household Night Consumption Study (2001), where per capita figures range between 0.6 and 1.7 with an average of around 0.9 l/capita/hour.

[9] Original Term (German): Nullverbrauchsmessung

INTERNATIONAL COMPARISON OF THE W392 LEAKAGE TARGETS

By comparing the ILI values in Table 6 to international data, it becomes obvious that they are truly ambitious. This reflects the generally good condition of the distribution systems and the excellent maintenance and asset management efforts. Similar (especially the low values) leakage levels in English distribution networks are only achievable with complex and sophisticated leakage management strategies (especially small DMAs and pressure management).

Leakage Level Classification in Australia

In the most recent Australian Training Materials (to be published early 2005) the water loss level classification is pretty much in line with the German targets.

ILI	Description
1 to 1.5	Excellent
1.5 to 2.0	Good
2.0 to 2.5	Reasonable
2.5 to 3.0	Fair
3.0 to 3.5	Poor
3.5 to 4.0	Unacceptable

Table 7: Australian Leakage Level Classification

AWWA Water Loss Control Committee Report

The calculated ILI targets are of special interest when comparing the German understanding and actual real loss levels to the AWWA recommendations and the situation in North America. The table provided in the committee report (see Table 8) recommends ILIs between 1 and 8, and only recommends ILIs between 1 and 3 for utilities with either very limited or expensive resources.

General Guidelines for Setting a Target Level with the Infrastructure Leakage Index			
Target ILI Range	**Water Resources Considerations**	**Operational Considerations**	**Financial Considerations**
1 - 3	Available resources are greatly limited and are very difficult and/or environmentally unsound to develop	Operating with system leakage above this level would require expansion of existing infrastructure and/or additional water resources to meet the demand	Water resources are costly to develop or purchase Ability to increase revenues via water rates is greatly limited due to regulation or low ratepayer affordability
3 - 5	Water resources are believed to be sufficient to meet long-term needs, but demand management interventions (leakage management, water conservation) are included in the long-term planning	Existing water supply infrastructure capability is sufficient to meet long-term demand as long as reasonable leakage management controls are in place	Water resources can be developed or purchased at reasonable expense Periodic water rate increases can be feasibly effected and are tolerated by the customer population
5 - 8	Water resources are plentiful, reliable and easily extracted	Superior reliability capacity and integrity of the water supply infrastructure make it relatively immune to supply shortages	Cost to purchase of obtain/treat water is low, as are rates charged to customers
Greater than 8	While operational and financial considerations may allow a long-term ILI greater than 8, such a level of leakage is not an effective utilization of water as a resource. Setting a target level greater than 8 – other than as an incremental goal to a smaller long-term target – is discouraged.		
Source: AWWA Water Loss Control Committee Report published in the AWWA Journal in August 2003 (Table 7, Page 76)			

Table 8: AWWA ILI Target Levels

SUMMARY

The W 392 guidelines are a major improvement to its predecessor. The IWA water balance with all its definitions was adopted (with very minor modifications) - which will allow German water utilities to engage in benchmarking with other utilities that use the IWA water balance - despite different languages.
But maybe even more important is how the understanding of real losses has changed and how much the (meanwhile internationally accepted) UK research, methodologies and strategies have influenced these new guidelines, for example:

- the expressive acknowledgement of the pressure:leakage relationship
- the recommendation to introduce DMAs
- the understanding of the importance of leak run-times
- the dominating importance of the service connection density.

Not surprisingly, the leakage level classification is ambitious - but it is pretty much in line with the Australian classification. On the negative side it has to be noted that a big opportunity was missed: to change the leakage performance indicator from m3/km main/hour to (at least) liters/service connection/day or even introduce the Infrastructure Leakage Index.

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